Wireless Power Transfer in 3D Space

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***Abstract*— The main objective of this project is to develop a system of wireless power transfer in 3D space. This concept based on low frequency to high frequency conversion. High frequency power is transmit between air-core and inductor. This work presents an experiment for wireless energy transfer by using the Inductive resonant coupling (also known as resonant energy transfer) phenomenon. The basic principles will be presented about this physical phenomenon, the experiment design, and the results obtained for the measurements performed on the system. The parameters measured were the efficiency of the power transfer, and the angle between emitter and receiver. We can achieve wireless power transfer up to 10watts in 3D space using high frequency through tuned circuit. The wireless power supply is motivated by simple and comfortable use of many small electric appliances with low power input.**

Keywords- HF Transformer; Air Core Inductor; BridgeRectifier; Resonant Coupling; Load.

I. INTRODUCTION

There is a basic law in thermodynamics; the law of conservation of energy, which states that *energy may neither be created nor destroyed just can be transformed*. Nature is an expert using this physicsfundamental law favouring life and evolution of species all around the planet, it can be said that we are accustomed to live under this law that we do not pay attention to its existence and how it influence our lives.

Nowadays, there are some daily life applications that could use an energy transport form without cables, some of them could be:

- Medical implants. The advance in biomedical science has allowed creating biomedical Implants like: pacemakers, cochlear implants, subcutaneous drug supplier, among others.
- Charge mobile devices, electrical cars, and unmanned aircraft, to name a few.
- Home appliances like irons, vacuum cleaners, televisions, etc.

A. *TESLA'S Vision*

Thus, in the early 19-nth century this prominent inventor and scientist performed experiments (Tesla (1914)) regarding the wireless energy transfer achieving astonishing results by his age. It has been said that Tesla's experiments achieved to light lamps several kilometers away.

Nevertheless, due to the dangerous nature of the experiments, low efficiency on power transfer and mainly by the depletion of financial resources, Tesla abandoned experimentation, leaving his legacy in the form of a patent that was never commercially exploited.

Electromagnetic radiation has been typically used for the wireless transmission of information. However, information travels on electromagnetic waves which are a form of energy. Therefore, in theory it is possible to transmit energy similarly like the used to transfer information (voice and data). In particular, it is possible to transfer in a directional way great powers using microwaves (Glaser (1973)). Although the method is efficient, it has disadvantages: requires a line of sight and it is a dangerous mechanism for living beings. Thus, the wireless energy transfer using the phenomenon of electromagnetic resonance has become in a viable option, at least for short distances, since it has high efficiency for power transfer. The authors of (Karalis et al. (2008); Kurs (2007)) claim that resonant coupling do not affect human health.

B. *Methodology*

At present, energy has been transferred wirelessly using such diverse physical mechanisms like:

- Laser.

The laser beam is coherent light beam capable to transport very high energies; this makes it in an efficient mechanism to send energy point to point in a line of sight. NASA (NASA (2003)) introduced in 2003 a remote-controlled aircraft wirelessly energized by a laser beam and a photovoltaic cell infra-red sensitive acting as the energy collector. In fact, NASA is proposing such scheme to power satellites and wireless energy transfer where none other mechanism is viable (NASA (2003)).

- Piezoelectric Principle (Hu et al. (2008))

It has been demonstrated the feasibility to wirelessly transfer energy using piezoelectric transducers capable to emit and collect vibratory waves.

- Radio waves and Microwaves

In (Glaser (1973)) is shown how to transmit high power energy through long distances using Microwaves. Also, there is

a whole research field for rectennas (J. A. G. Akkermans & Visser (2005); Mohammod Ali & Dougal (2005); Ren & Chang (2006); Shams & Ali (2007)) which are antennas capable to collect energy from radio waves.

- Inductive coupling (Basset et al. (2007)

Gao (2007); Low et al. (2009); Mansor et al. (2008)). The inductive coupling works under the resonant coupling effect between coils of two LC circuits. The maximum efficiency is only achieved when transmitter and receiver are placed very close from each other.

- "Strong” electromagnetic resonance

In (Karalis et al. (2008); Kurs (2007)) was introduced the method of wireless energy transfer, which use the "strong" electromagnetic resonance phenomenon, achieving energy transfer efficiently at several dozens of centimeter’s. Transferring great quantities of power using magnetic field creates, inevitably, unrest about the harmful effects that it could cause to human health. Therefore, the next section will address this concern.

C. Electromagnetic Waves and Health

Since the discovering of electromagnetic waves a technological race began to take advantage of transferring information wirelessly. This technological race started with Morse code transmission, but quickly came radio, television, cellular phones and the digital versions for all the mentioned previously. Adding to the mentioned before, in the last decade arrived an endless amount of mobile devices capable to communicate wirelessly; these kind of devices are used massively around the globe. As a result, it is common that an average person is subjected to magnetic fields in frequencies going from Megahertz up to the Gigahertz. Therefore, the concerns of the population about health effects due to be exposed to all the electromagnetic radiation generated by our society every day. Besides, added to the debate, is the concern for the wireless energy transfer mechanisms working with electromagnetic signals.

Several studies have been completed (Breckenkamp et al. (2009); Habash et al. (2009)) about the effects of electromagnetic waves, in particular for cellular phones, verifying that just at the upper international security levels some effects to genes are noticed. In (Peter A. Valberg & Repacholi (2007)) is assured that it is not yet possible to determine health effects either on short or long terms due by the exposition to electromagnetic waves like the ones emitted by broadcasting stations and cellular networks. Nevertheless, in (Valborg Baste & Moe (2008)) a study was performed to 10,497 marines from the Royal Norwegian Navy; the result for the ones who worked within 10 meters of broadcasting stations or radars, was an increase on infertility and a higher birth rate of women than men. This increase of infertility agrees with other study (Irgens A & M (1999)) that determined that the semen quality decay in men which by employment reasons (electricians, welders, technicians, etc.) are exposed to constant electromagnetic radiation including microwaves. These studies conclude that some effects on the human being, in fact occur, mainly at high frequencies.

D. Acousticand Electrical Resonance

The mechanical resonance or acoustic is well known on physics and consists in applying to an object a vibratory periodic action with a vibratory period that match the maximum absorption energy rate of the object. That frequency is known as resonant frequency. This effect may be destructive for some rigid materials like when a glass breaks when a tenor sings or, in extreme cases, even a bridge or a building may collapse due to resonance; whether it is caused by the wind or an earthquake. Resonance is a well known phenomenon in mechanics but it is also present in electricity; is known as electrical resonance or inductive resonance. Such phenomenon can be used to transfer wireless energy with two main advantages: maximum absorption rate is guaranteed and it can work in low frequencies (less dangerous to humans). When two objects have the same resonant frequency, they can be coupled in a resonant way causing one object to transfer energy (in an efficient way) to the other. This principle can be exploited to transmit energy from one point to another by means of an electromagnetic field. Next, three wireless energy transfer mechanisms are described.

E. Energy Transfer Mechanisms

Inductive coupling (Mansor et al.(2008)) is a resonant coupling that takes place between coils of two LC circuits with the same resonant frequency, transferring energy from one coil to the other as it can be seen in figure 1(a). The disadvantage of this technique is that efficiency is lost as fast as coils are separated.

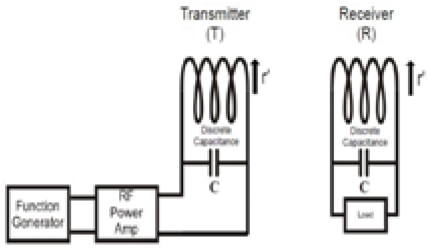

Figure 1. Inductive Coupling

F. Existing System

In case of 2D concept the appliance is restricted to movement along any determined surface which has different properties from the free space and serves for power transmission from the source to the appliance.

G. Proposed System

The wireless power supply is motivation to comfortable use of many small electric appliances with low power input.

In case of 3D concept the appliance can be moved in the determined free space through which power is transmitted from the source to the appliance with respect to the electromagnetic field character.

II. IMPLEMENTATION

Fig. 2 and Fig. 3 shows the Block Diagram and Schematic Diagrams of proposed system respectively.

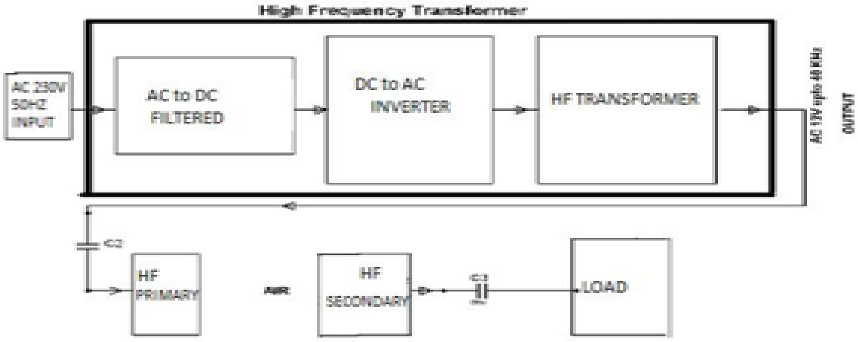

Figure 2. Block Diagram

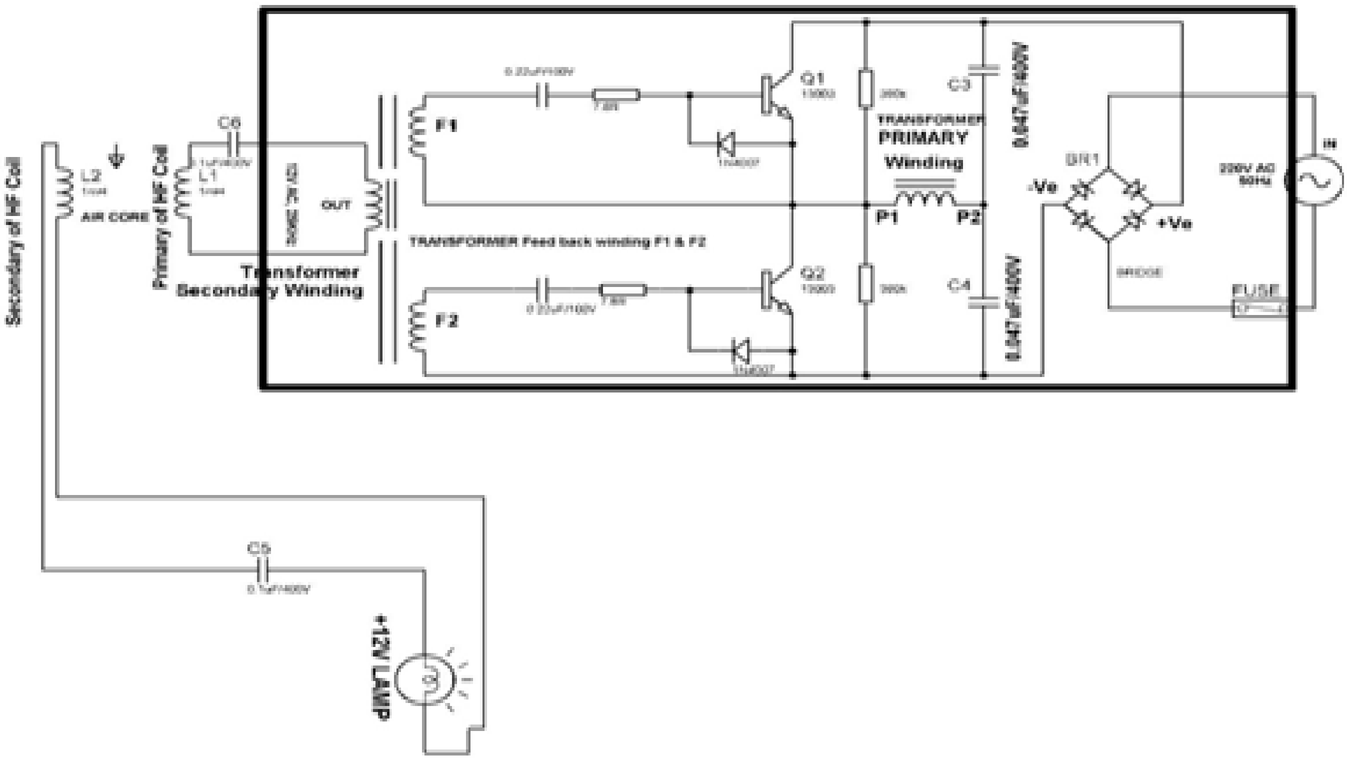

Figure 3. Schematic Diagram

A. Operation

The AC 50 Hz is rectified by the bridge positive passes through Q1 (while f1 provides the bias) from collector to emitter, then P1, then P2 then C4 to reach negative. Next F2 provides bias to Q2 that stops Q1 while positive flows through C3, then P2, then P1, then Q2 and then negative. Thus P1 to P2 in one half cycle and then P2 to P1 in next half cycle develops AC in secondary, the DC derived from This project is formed out of an AC 230V 50Hz to AC 40 KHz at 12V circuit. that is again made to ac by an inverter by transistors switching near 40 KHz which is fed to another high frequency transformer, in side a metal box to avoid electrical noise electrical noise spread and prevent shock hazard, the output of which is then fed to a resonating coil acting as primary of another air core transformer, the secondary of which is fed to a drive a DC load. The air core transformer operating near 40 KHz is the main concept for wireless power transfer in 3 D space as one cannot transfer 50 Hz ac power by air core .

The secondary coil in resonance develops a voltage of 40 KHz at about 12volt while it is taken over the primary coil. A capacitor is a passive electronic component consisting of a pair of conductors separated by a dielectric (insulator). When there is a potential difference (voltage) across the conductors, a static electric field develops in the dielectric that stores energy and produces a mechanical force between the conductors. An ideal capacitor is characterized by a single constant value, capacitance, measured in farads. This is the ratio of the electric charge on each conductor to the potential difference between them, the main purpose are used to match resonant frequency. The output of this secondary is given to a 10 watt lamp that glows at considerable distance from the primary coil.

III. HARDWARE COMPONENTS

- High Frequency Transformer
- Coil
- LED
- Capacitor

A. High Frequency Transformer

The transformer is one of the simplest of electrical devices. Its basic design, materials, and principles have changed little over the last one hundred years, yet transformer designs and materials continue to be improved. Transformers are essential in high voltage power transmission providing an economical means of transmitting power over large distances.

The simplicity, reliability, and economy of conversion of voltages by transformers was the principal factor in the selection of alternating current power transmission in the "War of Currents" in the late 1880's. In electronic circuitry, new methods of circuit design have replaced some of the applications of transformers, but electronic technology has also developed new transformer designs and applications.

Transformers come in a range of sizes from a thumbnail-sized coupling transformer hidden inside a stage microphone to giga watt units used to interconnect large portions of national power grids, all operating with the same basic principles and with many similarities in their parts.

B. LITZ WIRE

Liza Wire is a type of cable used in electronics to carry alternating current. The wire is designed to reduce the skin effect and proximity effect losses in conductors used at frequencies up to about 1 MHz. It consists of many thin wire strands, individually insulated and twisted or woven together; following one of several carefully prescribed patterns often involving several levels (groups of twisted wires are twisted together, etc.). This winding pattern equalizes the proportion of the overall length over which each strand is at the outside of the conductor. The term Litz wire originates from Litzendraht, German for braided/ stranded wire or woven wire.

C. Capacitor

A capacitor or condenser is a passive electronic component consisting of a pair of conductors separated by a dielectric. When a voltage potential difference exists between the conductors, an electric field is present in the dielectric. This field stores energy and produces a mechanical force between the plates. The effect is greatest between wide, flat, parallel, narrowly separated conductors the potential difference between them. In practice, the dielectric between the plates passes a small amount of leakage current. The conductors and leads introduce an equivalent series resistance and the dielectric has an electric field strength limit resulting in a breakdown voltage.

The properties of capacitors in a circuit may determine the resonant frequency and quality factor of a resonant circuit, power dissipation and operating frequency in a digital logic circuit, energy capacity in a high-power system, and many other important aspects.

A capacitor (formerly known as condenser) is a device for storing electric charge. The forms of practical capacitors vary widely, but all contain at least two conductors separated by a non-conductor. Capacitors used as parts of electrical systems, for example, consist of metal foils separated by a layer of insulating film.

Capacitors are widely used in electronic circuits for blocking direct current while allowing alternating current to pass, in filter networks, for smoothing the output of power supplies, in the resonant circuits that tune radios to particular frequencies and for many other purposes.

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The capacitance is greatest when there is a narrow separation between large areas of conductor, hence capacitor conductors are often called "plates", referring to an early means of construction. In practice the dielectric between the plates passes a small amount of leakage current and also has an electric field strength limit, resulting in a breakdown voltage, while the conductors and leads introduce an undesired inductance and resistance.

D. Theory of Operation

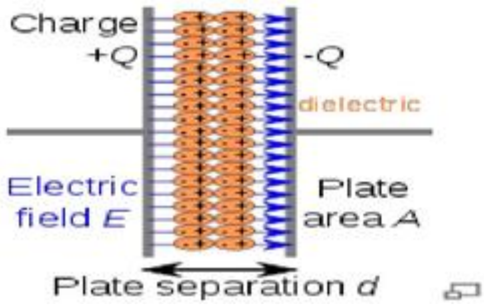

Figure 4. CAPACITOR PLATES

Charge separation in a parallel-plate capacitor causes an internal electric field. A dielectric (orange) reduces field and increases the capacitance.

E. Energy Storage

Work must be done by an external influence to "move" charge between the conductors in a capacitor. When the external influence is removed the charge separation persists in the electric field and energy is stored to be released when the charge is allowed to return to its equilibrium position. The work done in establishing the electric field, and hence the amount of energy stored, is given by:

$$W = \int_{q=0}^{Q} V dq = \int_{q=0}^{Q} \frac{q}{C} dq = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2 = \frac{1}{2}VQ \ldots\ldots\ldots (1)$$

F. Analysis

The inductance of single-layer air-cored cylindrical coils can be calculated to a reasonable degree of accuracy with the simplified formula

$$\mu H = \frac{R^2N^2}{9R+10L} \quad \text{.......... (2)}$$

where Henry [μH] (microhenries) are units of inductance, R is the coil radius (measured in inches to the center of the conductor), N is the number of turns, and L is the length of the coil in inches. The online Coil Inductance Calculator calculates the inductance of any coil using this formula. Higher accuracy estimates of coil inductance require calculations of considerably greater complexity.

Note that if the coil has a ferrite core, or one made of another metallic material, its inductance cannot be calculated with this formula.

G. OUTPUT

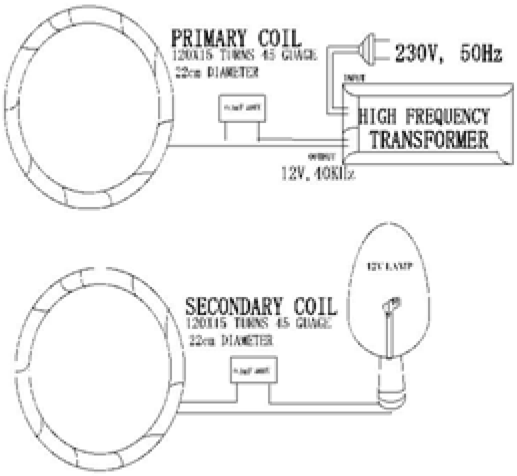

Figure 5. Layout Diagram

Figure 6. Our Demo

Figure 7. Applications in Real Time

IV. CONCLUSION

The coils are wrapped around a hollow ferromagnetic core, in a solenoid shape. 45-gauge copper wire with enamel covering (for insulation) is used for the windings. Note that the two coils will ideally only be separated by the thickness of the plastic chassis during transmission.

The pickup is inductively coupled to the transmission coils, meaning that the hand-wound inductive pickup coil is positioned close to and aligned with the transmission coil. Then the magnetic field produced by the transmitter passes through the dense loop of wires, inducing an electrical current. By maximizing the inductive coupling of the pickup coil in this block with the transmitting coil, the magnitude of the induced current is optimized by the four diodes in the schematic form a full-wave bridge rectifier, and the capacitor filters the output voltage into constant DC signal. The output of this secondary is given to a 10 watt lamp that glows at considerable distance from the primary coil. However, the overall efficiency of the power transfer is less than 70% for all weakly coupled series resonators used in the project. The project can be enhanced in future up to 1 meter distance in space using resonators with a Q factor of 1,000 enabling it to send power over a distance 9 times the radius of the coil of 11 CMs .

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